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OBESITY

I. As Related to Health and Disease

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OBESITY

I. As Related to Health and Disease

By RUTH WOODS

The greatest problem in nutrition and preventive medicine in the United States today has been said to be obesity (1). It has been estimated that more than one-fifth of the population of the United States over 30 years (about 15 million people) is overweight by 10 percent or more. Both clinical and life insurance studies show that overweight is a major factor in shortening life expectancy. It may also be an etiological or complicating factor in some of the principal degenerative diseases of middle and later life. These include cardiovascular diseases, such as heart failure, hypertension, arteriosclerosis; diabetes, gallbladder disease and others.

In many of these studies the criterion of overweight has been the excess weight in pounds over a so-called "standard" or average weight for a given height, sex and age. In recent years, it has become apparent that this definition of overweight is inadequate. In view of the implications of obesity and overweight, it is extremely thought-provoking that there exists at the present time no clear definition of obesity.

This Review will attempt two things: (1) To discuss obesity in the light of recently developed concepts concerning its measurement, and (2) to indicate its incidence in the United States today and the toll it exacts in terms of increased morbidity and mortality.

A subsequent Review will describe the causes of obesity as they are understood today and methods for its prevention and cure.

Overweight — Incidence and Effect:

Most of the information concerning overweight and its relation to health and disease has been derived from life insurance statistics. These studies show that obesity is the most frequent physical abnormality found in the general population of this country. Data in 1930 showed that 28 per cent of persons examined for insurance was 10 per cent or more overweight (2) (Table 1).

The percentage of overweight increases with advancing age and is greater in women than in men after the age of thirty-five. Other studies show that overweight is a major hazard to health and life, especially after the age of thirty. Table 2 and Fig. 1 show the relationship between the death rate for all causes and all ages as a function of weight as determined by the studies of Dublin and Marks (3).

TABLE 1.

Percentage Incidence of Overweight and Underweight Among 10,000 Examinees (2)

		Actual	Standardized†
Overweight 10% or more	Men	25.8	25.7
	Women	30.9	30.3
	Total	27.3	28.0
Underweight 10% or more	Men	10.2	10.2
	Women	15.8	15.3
	Total	11.9	12.8

†Standardized for age and sex according to the population of the United States in 1930.

These data show an overall increase in death rate of 22 per cent for those whose weights are 5—14% greater than average, up to 74 per cent increase in death rate for those whose weights are greater than 25% above average.

It has been pointed out by Armstrong, Dublin, Wheatley and Marks (4) that these studies include only the best risks of the obese individuals—those with other physical impairments or chronic illnesses having been rejected. They note, further, that because of this, these statistics actually understate the full effect of obesity on mortality.

The importance of overweight as a factor in mortality increases with age (5). Table 3 shows the effecet of overweight on mortality for ages under and over 45. Earlier studies cited by Fisk (6) show likewise that persons in middle life who weigh 20 pounds more than the average incur an extra 25% mortality risk. Because of the increasing percentage of older persons in our population, these data become especially significant. Table 4 shows the influence of overweight on mortality in persons 45 to 50 years of age (7).

TABLE 2.

Deaths per 100,000 — All Causes — All Ages Combined by Weight Classes (2)

	Death rates per 100,000	Percentage of rate in "normal" weight class
Underweights		
15% to 34% underweight	913	108
5% to 14% underweight	833	99
Normal weights	844	100
Overweights		
5% to 14% overweight	1,027	122
15% to 24% overweight	1,215	144
25% or more overweight	1,472	174

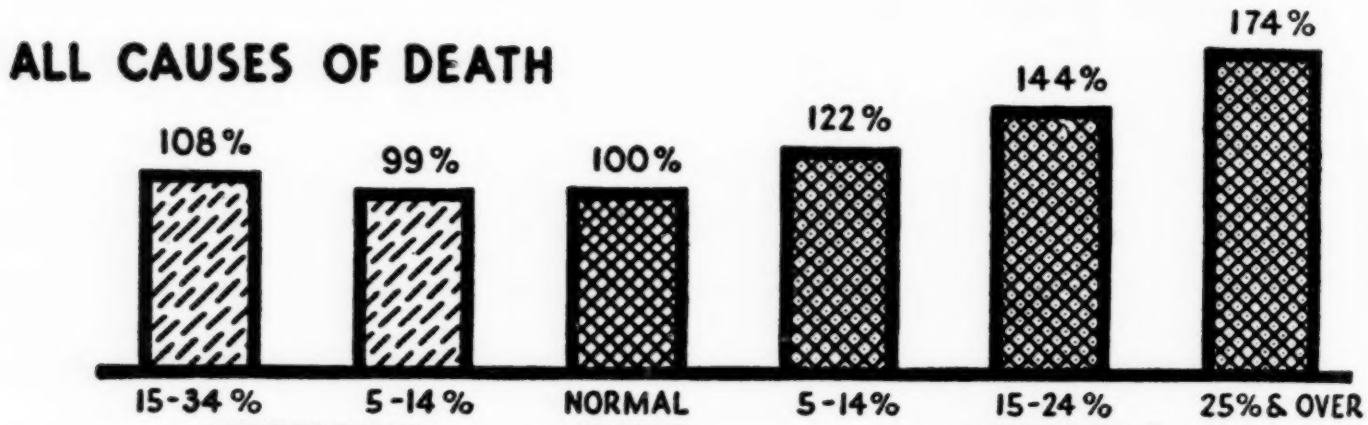
TABLE 2a

Standardized Death Rates per 100,000 for Specified Causes of Death, All Ages Combined, by Weight Classes — Based on the Mortality Experience of About 200,000 Insured Lives (3)

Cause of Death	Standardized Death Rate per 100,000							
	Underweight			Normal Weight	Overweight			
	Total	15–34%	5–14%		5–14%	15–24%	25% +	Total
All causes	848	913	833	844	1,027	1,215	1,472	1,111
Organic heart diseases	65	63	66	80	115	135	129	121
Angina pectoris	14	12	14	16	32	39	37	35
Diseases of the arteries	17	15	17	23	34	46	41	38
Acute and chronic nephritis	63	56	64	82	108	202	224	141
Cerebral hemorrhage and apoplexy	49	46	50	70	101	115	170	110
Cancer	62	54	64	61	64	73	86	68
Diabetes	9	9	9	14	22	45	117	36
Pulmonary tuberculosis	115	166	103	57	28	21	*	26
Pneumonia (lobar and unspecified)	70	90	66	63	56	64	72	59
Influenza	20	29	18	20	29	24	*	28
Accidents	55	44	58	60	65	65	87	67
Suicide	27	33	25	24	31	29	42	31

* Not significant.

FIG. 1—"Influence of Body Weight on Mortality" (3)
Subsequent mortality among men, according to build classes, expressed as percentage of death rate of normal weight men.



Overweight and Disease: The relationship of body weight to mortality from specific important causes of death is illustrated in Fig. 2 (3).

It can be seen that overweight is especially important in the so-called degenerative diseases — cardiovascular-renal disease and diabetes. With the development of the antibiotics and other means of controlling infections, the infectious diseases such as pneumonia have fallen off sharply as factors in mortality. This, combined with the advancing age level of the population,

TABLE 3. Influence of Weight on Mortality as Modified by Age
Deaths per 100,000

Weight	Age in Years: Under 45	Age in Years: Over 45
Standard	463	1308
Underweight, total	498	1274
Overweight, total	527	1824

TABLE 4

Influence of Overweight on Mortality in Persons Aged 45 to 50 Years (7)

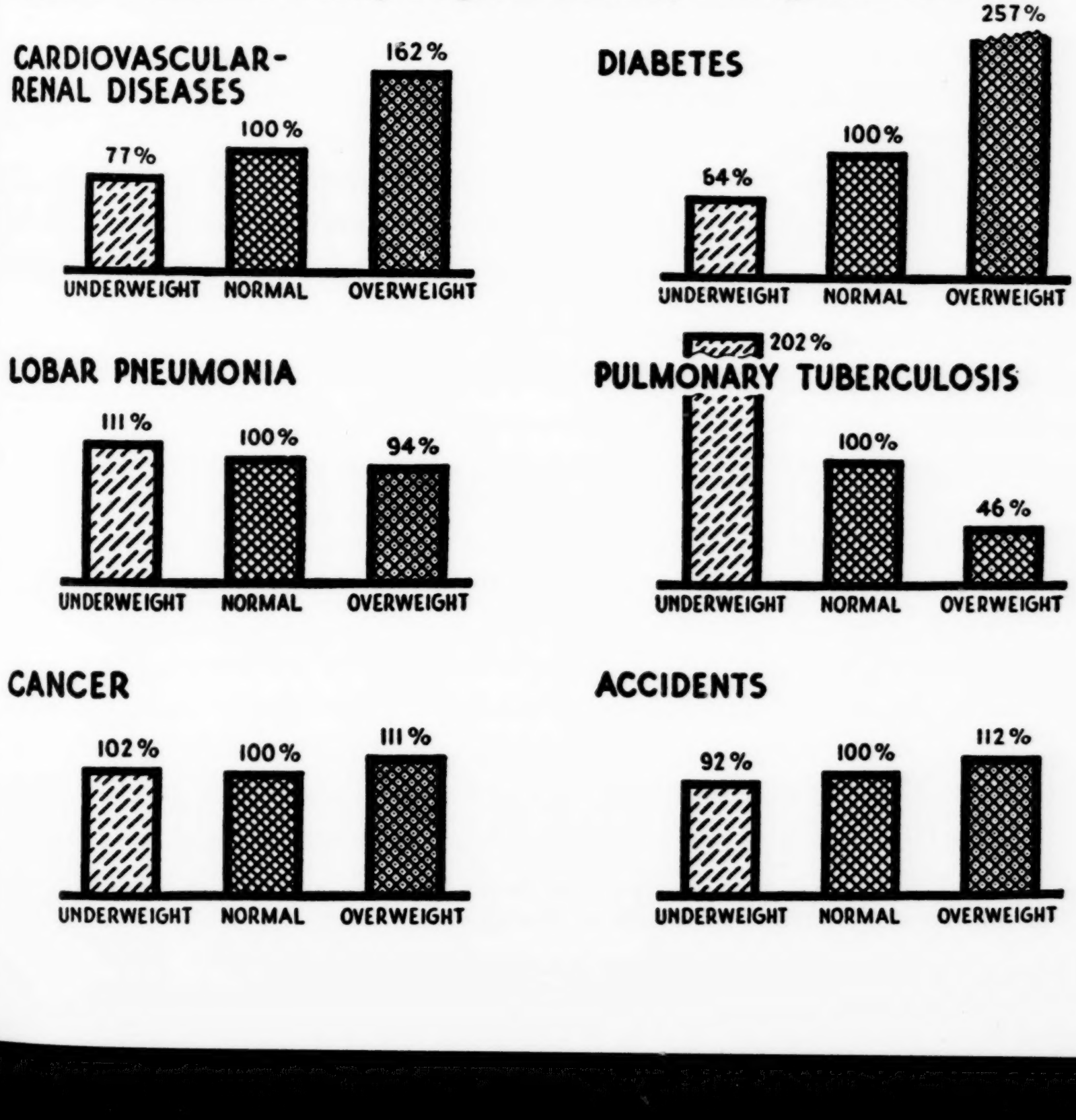
Pounds overweight	Increase in death rate over average, per cent
10	8
20	18
30	28
40	45
50	56
60	67
70	81
90	116

makes the degenerative diseases characteristic of middle and later life, especially important as factors in mortality. And it is just in these diseases that overweight is an important factor.

Many studies have shown the adverse influence of obesity on hypertension, diabetes, heart disease, cancer, acute and chronic nephritis, cirrhosis of the liver, atherosclerosis, toxemias of pregnancy. In surgery also it is well recognized that obesity increases operative risk and the rate of mortality. It has been shown that many cases of arthritis are more severe in the obese. There is an increased incidence of gallbladder disease, earlier appearance of varicose veins, more frequent fractures and a greater incidence of accidents in the obese (8). The importance of obesity as a complicating factor in these diseases has been well recognized by clinicians. Thus, Joslin has termed diabetes, "the fat man's folly," and the typical gallbladder patient has been described as "fair, fat and forty."

(Cardiovascular Disease): Statistical evidence shows that the death rate of overweights from heart disease and from cerebral hemorrhage is 1½ times that of average weights. For angina pectoris, the difference is even larger

FIG. 2—"Influence of Body Weight on Mortality from Specific Causes" (3)



(9). Master, Dublin and Marks (4) surveyed 74,000 industrial workers and found that at every age and in both sexes a steady progression in average blood pressure occurred with increase in body weight for height. In general, the largest differences were found at the older ages and among women. Armstrong *et al* (4) cite evidence from the literature for the fact that significant deviations from the normal electrocardiogram are also relatively most frequent in overweight individuals — approximately 15 per cent of overweights showing such impairment as compared to 8½ per cent among average weights.

Wilens' study on autopsy material shows the common association between vascular change and obesity (9a). He divided his cases in three groups according to the state of nutrition evaluated at autopsy. Considering only evidence of advanced atherosclerosis, he found that the obese had a consistent and marked excess in the proportion with this condition. For example, at ages 45 to 54, 20 per cent of the obese had advanced changes in the arteries as compared with 6.7 per cent of those classes as of poor nutritional status; at 65 to 74 the proportions were 45.3 per cent and 20.2 per cent, respectively. Coronary atherosclerosis of advanced degree was also more frequent in the obese than in the others, the difference being especially great in males.

(Diabetes): The most striking effects of overweight in disease are found in diabetes. The death rate of overweights from this disease is 2½ times that among average weights. Moreover, the margin between overweights and those of slighter build increases rapidly as the degree of overweight advances. Thus, among those who are actually stout (25 per cent or more overweight), the diabetes death rate is more than eight times that of average weight persons (9). Joslin and associates (9b) found (using as a basis the previous maximum weight prior to onset of diabetes) that in patients 40 and over at onset, 60 per cent were at least 20 per cent over average weight and an additional 25 per cent moderately overweight, or a total of 85 per cent with some degree of overweight. Only 5 per cent were underweight.

(Other Diseases): Gallbladder disease is especially frequent in overweights, a study of applicants for life insurance indicating that 41 per cent of the males and 53 per cent of the females with a history of this disease were overweight (4). Overweight is believed to be a common etiological factor in degenerative arthritis and has been shown also to be a common occurrence in the development of hernia in men and a probable factor in the incidence of cancer of the uterus in women.

Even fatal accidents are more common among overweights, and their incidence varies directly with the degree of overweight. This has been explained by clumsiness or lack of physical agility resulting from overweight.

It is interesting also that the suicide rate is greater among overweights than among those of average weight (9). The reason for this is not clear, but it has been suggested that possibly psychological maladjustments related either to overweight itself or to defects associated with overweight may play a part.

These implications concerning obesity have been further emphasized by more recent studies of the Metropolitan Life Insurance Company (4), as yet unpublished, but reported at the 100th Annual Session of the American Medical Association on June 12, 1951. These are concerned with individuals insured between 1925 and 1934, traced up to 1950. They tell a familiar story. Uniformly, the death rates of overweights were substantially higher than normal. In the aggregate, overweight men and women had 1½ times the standard mortality. Most of these extra deaths were due to degenerative diseases of the heart, circulatory system and kidney. Diabetes showed more than three times the expected mortality. In overweights, the mortality from cirrhosis of the liver was far above normal, as was that due to gallbladder disease.

These recent studies, as well as the older ones, may be summed up in Table 5.

TABLE 5

Effect of Weight on Mortality of Insured Men, Standard and Substandard Issues Combined, by Ages at Issue; Experience for 1909 to 1928

Build Group	Percent Actual of Expected Deaths			
	Ages 20–29	Ages 30–39	Ages 40–49	Ages 50–59
Underweights:				
15% or more	115	103	85	79
5% to 14%	101	95	77	82
Average weight	93	84	86	93
Overweights:				
5% to 14%	99	90	97	91
15% to 24%	107	120	117	118
25% to 34%	134	137	141	122
35% or more	163	137	141	143

Note: These data relate to men 5′3″ to 6′2″ in height.

Source: Actuarial Society of America and the Association of Life Insurance Medical Directors of America, "Supplement to Medical Impairment Study," New York, 1932.

Obesity — Nature and Recognition:

The previous section showed the significance of overweight as a factor in the incidence of specific diseases and in over-all mortality. Most of the insurance data, which serve as a basis for these studies, refer to overweight merely as the excess number of pounds over the standard or normal or aver-

age weight for a given height, sex and age. It has been widely recognized in recent years that this definition requires further elaboration. The Metropolitan Life Insurance Company, for example, issued a table of so-called "ideal" weights for men and women (10, 11); ideal, defined in terms of longevity. These weights are those of maximum life expectancy as determined by their statistical information. In these tables, adjustment is made for body frame differences, i.e. small, medium and large frames (Tables 6 and 7).

TABLE 6

Ideal Weights for Men of Ages 25 and Over

Weight in pounds according to frame (as ordinarily dressed)

Height (with shoes on) Feet	Inches	Small Frame	Medium Frame	Large Frame
5	2	116–125	124–133	131–142
5	3	119–128	127–136	133–144
5	4	122–132	130–140	137–149
5	5	126–136	134–144	141–153
5	6	129–139	137–147	145–157
5	7	133–143	141–151	149–162
5	8	136–147	145–156	153–166
5	9	140–151	149–160	157–170
5	10	144–155	153–164	161–175
5	11	148–159	157–168	165–180
6	0	152–164	161–173	169–185
6	1	157–169	166–178	174–190
6	2	163–175	171–184	179–196
6	3	168–180	176–189	184–202

Insurance companies have also recognized that different types of overweight exist. The pot-bellied variety of overweight is regarded as the most serious type. Overweights whose abdominal girth was more than 2 inches greater than chest girth at full expansion had an extra mortality of approximately 50% over and above the excess mortality associated with overweight itself (9).

In contrast to the ease of definition of "overweight," the term "obesity" is much more difficult to define. The distinction among the various classes

of overweight, however, make the definition and measurement of obesity important. Qualitatively, and especially in extreme cases, obesity is easily recognized. No one questions that "Mr. Five by Five," weighing 300 lbs., is obese. Quantitative definition of the term is much more difficult, especially in those borderline cases where the overweight is of the order of 10 to 20 per cent. Even this relatively small amount of overweight is significant, as can be seen from mortality tables. Brozek and Keys (12) have pointed out the limitations of height-weight tables as a criterion of obesity. Thus, individuals of standard weight for a given height, but of different ages, often show marked differences in body fat.

TABLE 7

Ideal Weights for Women of Ages 25 and Over (11)

Weight in pounds according to frame (as ordinarily dressed)

Height (with shoes on) Feet	Inches	Small Frame	Medium Frame	Large Frame
4	11	104–111	110–118	117–127
5	0	105–113	112–120	119–129
5	1	107–115	114–122	121–131
5	2	110–118	117–125	124–135
5	3	113–121	120–128	127–138
5	4	116–125	124–132	131–142
5	5	119–128	127–135	133–145
5	6	123–132	130–140	138–150
5	7	126–136	134–144	142–154
5	8	129–139	137–147	145–158
5	9	133–143	141–151	149–162
5	10	136–147	145–155	152–166
5	11	139–150	148–158	155–169

In the last 10 years, a number of methods have been described for evaluating body fat or the state of fatness-leanness in an effort to provide a quantitative measure of obesity.

It is easy to estimate clinically by examination or by pinching a person whether he is roughly fat or lean. The exact determination of the actual degree of fatness in a living person is not easy. At autopsy, the amount of fat or adipose tissue can be examined and measured directly, either by dissection or chemically, by extraction. Very few studies of a quantitative na-

ture have been made on the actual fat content of human bodies. Mitchell *et al* (13) reported the total amount of body fat on a single individual. This was a white man, aged 35, weighing 70.6 kilos and 183 cm. tall (155 lbs. and 72 inches), who had died of a heart attack. This individual was approximately 10 per cent underweight with reference to the standard height-weight tables. In this lean individual (who may not have been of normal body makeup) the body fat as measured by ether extraction was 12.5% of the total body weight. Detailed fat contents for the various body tissues were also determined. It is interesting to note that the adipose tissue contributed about 45 per cent of the total body fat; the skeleton (presumably in the bone marrow) contained about 19.5 per cent of the total body fat, while the striated muscle contained only 8 per cent. The adipose tissue itself made up 13.6% of the body weight and had the following composition:

Fat	42.4%
Protein	7.0
Ash	0.5
Water	50.1

Methods for Measuring Body Fatness in Vivo:

It is obvious that for measuring the amount of body fat in the living person, indirect methods must be used. Most promising of such methods devised, are the following:

Skin Fold Technique: As previously indicated, pinching the skin is an old clinical procedure commonly used to estimate the fatness or leanness of a patient. Many attempts have been made to refine this technique in order to more accurately evaluate the amount of subcutaneous adipose tissue. The human skin itself is both thin and relatively constant in this thinness (14). Thus, Edwards in measurements of the skin of cadavers, found that the average thickness of the double skin measured at 53 points on the body varied only between 1 and 4 mm., with an average of 2.2 mm; the values exceeding 3 mm. in less than 10 per cent of the locations. The thickness of skin folds — obtained by lifting the skin at different points of the body surface — varied, on the other hand, from 5 to 39 mm. This marked variation is due to the differences in the layer of subcutaneous fat tissue. This fact makes it possible to use the skin fold technique as a measure of fatness. Care must be taken, however, to use an adequate number of skin fold points and to make measurements with calipers under defined conditions of pressure. The usefulness of such a skin fold technique has been noted by Sinclair (15) in connection with the work of the Oxford Survey team evaluating nutritional status. The skin fold technique is at best only a semi-quantitative, or relative measure of body fat. Individuals differ in the distribution of body

fat. Some have fat legs or thighs, fat abdomens, and so on. This means that the skin fold thicknesses determined in these regions must be properly weighted in order to obtain an accurate estimate of the over-all body fat of the individual.

X-Ray Measurements: X-ray techniques have been developed for determining the thickness of the subcutaneous layer of fatty tissue. Stuart, Hill and Shaw (16) took X-rays of the lower leg and determined from the differing film densities of the separate areas on the photograph, the amount of bone, muscle and cutaneous plus subcutaneous tissue. Other investigators have used a similar technique for different parts of the body.

The limitation of the X-ray method lies in (1) the difficulty of the procedure and the equipment required and (2) in the fact that, as considered in the skin fold technique, individuals vary in the distribution of body fat. Reynolds and Asakawa (16a) attempted a measurement of "total fat" in children by measuring the fat layer in six areas of the body: calf, hips, waist, chest, upper and lower arm. This procedure is more accurate than X-ray of a single area, but involves considerably greater effort.

Specific Gravity: The density of body fat is considerably less than that of the other body tissues such as the skeleton, muscles, blood, etc. This fact makes it possible to determine the fat content of the body by measuring the over-all body density or specific gravity. Behnke *et al* (17, 18) used the following calculated values for densities: bone, 1.60; fat, 0.94; and residual body tissue, 1.06. (The bone density here mentioned is that of the marrow-filled or wet bone.) Other investigators have given slightly different values for these densities.

If the relative proportions of body fluid, muscle and bones remain roughly constant in persons of different sizes, the variations in specific gravity of the body can be used as an index of the fat content. The greater the fat content, the lower the specific gravity.

In such measurements of specific gravity, the volume of air in the lungs must be corrected for. Behnke *et al* measured the specific gravities of a large number of Navy personnel as well as those of a group of professional athletes by weighing in air and under water, using a weighted lead belt. The correction for lung volume was made by using a known mixture of helium and oxygen for breathing purposes. The subjects breathed this mixture until all the nitrogen in the lungs was displaced. Following this, the helium mixture was washed out by breathing normal air and the total helium was collected and measured. From these data, the lung volume was readily calculated, and the proper correction made.

Behnke estimated that a human body comprising 10 per cent of the body weight as bone, 10 per cent as essential fat and the rest as lean muscle and

soft tissue — with no excess adipose tissue — would have a specific gravity of 1.099. Addition of excess adipose tissue amounting to 10, 20 or 33 per cent of total body weight was calculated to yield 1.080, 1.062 and 1.036, respectively, as the values for specific gravity.

Rathbun, Pace *et al* (19, 20, 21) attempted to confirm the relationship between specific gravity and body fat. Using guinea pigs, they determined density values and fat content by direct experiment. As a result of their studies, they arrived at an equation for estimating human body fat and constructed tables relating specific gravity directly to fat content.

This work confirms the concept of a "lean body mass," relatively constant in its chemical composition and density. Body fat may be considered to act as a diluent to lean body mass and accordingly to change the specific gravity. Behnke *et al* (17) followed the specific gravity during weight reduction and found that in a subject whose weight was decreased by means of diet and exercise from 202.5 lbs. to 183 lbs., the specific gravity increased from 1.056 to 1.071. The specific gravity of the tissue lost in reduction was calculated as .937, indicating that the reduction in weight was almost solely due to loss of adipose tissue.

Behnke found an interesting correlation between specific gravity and the difference between abdominal and chest circumferences, the latter both measured with the subject standing erect and with palms in contact over the head. Among men of the same average height, he was able to distinguish three groups:

GROUP A: Low specific gravity range, from 1.021 to 1.059.
Average difference in circumference between chest and abdomen, 3.7 inches
Average height, 69 inches; average weight, 176 lbs.

GROUP B: Intermediate specific gravity range, from 1.060 to 1.074
Average difference in circumferences, 5.4 inches
Average height, 68.3 inches; average weight, 157 lbs.

GROUP C: High specific gravity range, from 1.075 to 1.097
Average difference in circumferences, 5.7 inches
Average height, 69.7 inches; average weight, 148.7 lbs.

These data indicate that (1) excess adipose tissue accounts for the difference in specific gravity among the several groups; (2) that a simple measurement of chest and abdominal girth will give a rough measure of specific gravity and body fat for a homogeneous group of individuals of similar physical build.

In another interesting study made by these authors (18) a group of 25 professional football players was examined. These men averaged 200 lbs. in weight. For their respective heights, their body weights were 25 per cent

above Army standards. Using "overweight" — defined as excess over standard weight — 17 of these 25 athletes could have been rejected by the Army or might have been refused life insurance as "poor risks."

Actually these men were lean, low in body fat, well-muscled and in top physical condition. Whether this type of "overweight" carries the same mortality hazard as overweight due to obesity has not been determined.

Water Content: Fat has a much lower water content than other body tissues. On this basis Pace and Rathbun were able to derive a relation between water content and fat content of the whole body, in man as well as in animals.

Furthermore in their work with guinea pigs, Pace and Rathbun (21) found that the water content of the lean, fat-free body mass is a highly constant value, 72.4 per cent ± 2.1 per cent. This makes it possible to estimate body fat by measuring the total water content of the body.

A number of methods using isotopic or dye tracers are available for this purpose (22). Steele and associates (23) used antipyrine, a water-soluble drug. In their method, a dose of antipyrine is injected and after waiting several hours for equilibration throughout the water content of the body, a sample of the blood is withdrawn and the concentration of the drug in the plasma measured. From the degree of dilution of the drug, it is possible to estimate the total amount of body water. Satisfactory correlation has been obtained between this method and the use of deuterium tracers, as well as between body fat estimated from water content and from specific gravity measurements.

Conclusion:

The importance of overweight as a primary factor in increasing morbidity and mortality is well recognized from both clinical and life insurance studies. At the present time, it is recognized that abdominal girth or flabbiness — both measures of body fat or obesity — have an influence in increasing mortality over and above the excess mortality associated with overweight itself. The significance of body fat content, as distinguished from overweight *per se,* in influencing the incidence of disease and death requires further study.

It is interesting to note that no insurance data exist which differentiate between the mortality risks incurred by overweight due to increased muscle mass or by overweight due to accumulation of excess fatty tissue.

It has been recognized that overweight must be further defined. The development of methods for a more quantitative measure of obesity by means of estimation of body fat, makes it possible to distinguish various types of overweight.

The application of these methods and the development of statistical data showing the correlation between morbidity and mortality and content of body fat, as well as of overweight *per se*, may be expected to be extremely valuable tools in modern preventive medicine.

As this Review goes to press a recent article by Brozek, J. and A. Keys (24) has appeared, which stresses the importance of specific gravity as a method of determining fatness or leanness in man and makes an attempt to establish fatness-leanness norms.

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